MESA and NuGrid Simulations of Classical Nova Outbursts and Nucleosynthesis

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- MESA is a collection of Fortran-95 Modules for Experiments in Stellar Astrophysics (http://mesa.sourceforge.net)

- Its main module STAR can be used for 1D simulations of stellar evolution

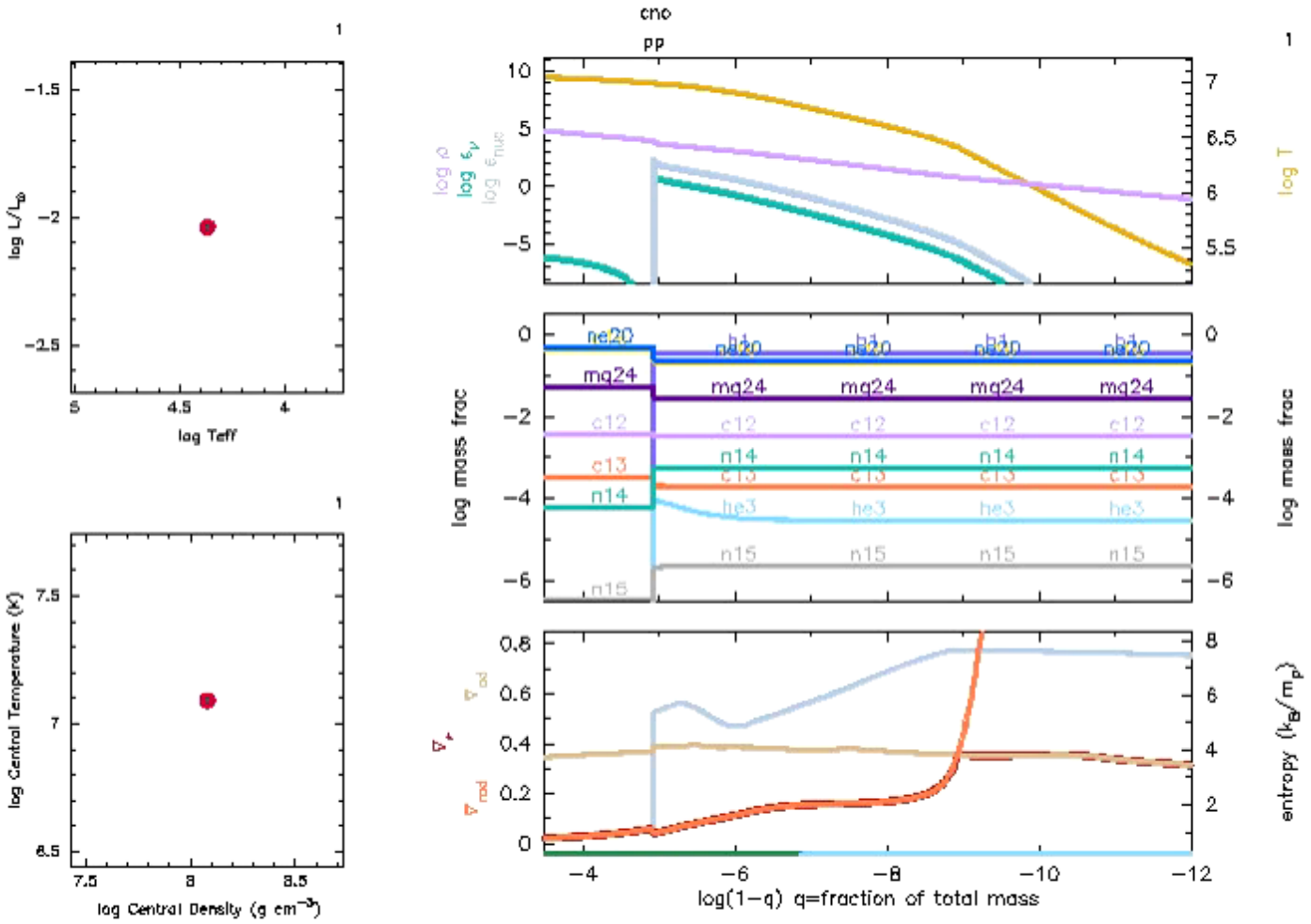
- Other MESA modules provide STAR with state-of-the-art numerical algorithms and modern input physics

- NuGrid collaboration (http://nugridstars.org) has developed two post-processing nucleosynthesis codes that use the same physics and solver packages: SPPN for serial computations at a single mass zone inside a star (T(t) and ρ(t) trajectories have to be provided), and MPPNP for multi-zone parallel computations (needs detailed stellar models, e.g. from MESA)

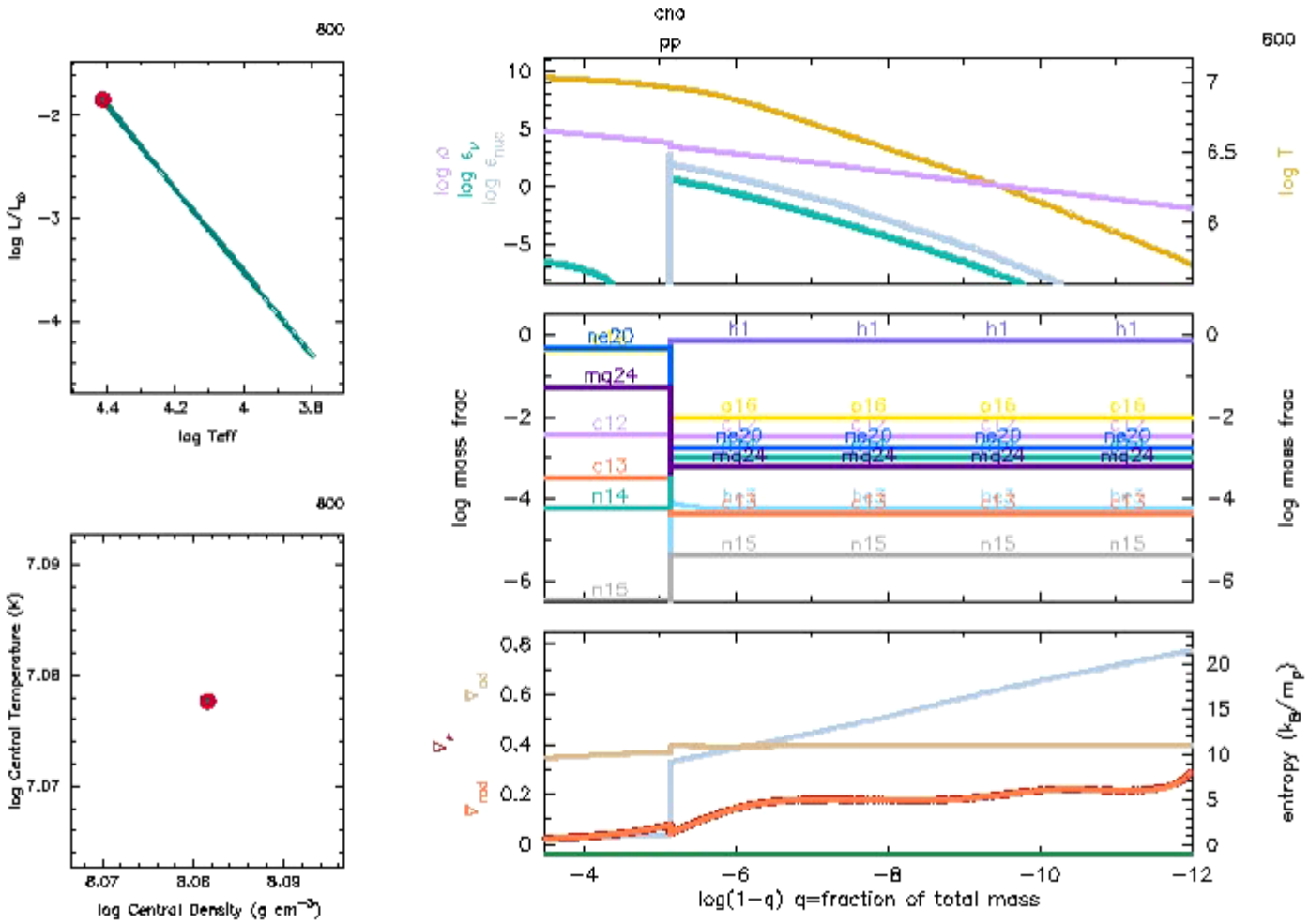
- Nova Framework combines MESA and NuGrid into an easy-to-use research tool that can be used to model nova outbursts and nucleosynthesis

- This presentation demonstrates Nova Framework's capabilities

A nova outburst occurring on a 1.15M_{sun} ONe white dwarf with T_c = 12 MK that accretes a mixture of equal amounts of its core and solar-composition materials with the rate of 2×10^{-10} M_{sun}/yr; such pre-mixed 1D nova models are used to mimic the interface mixing

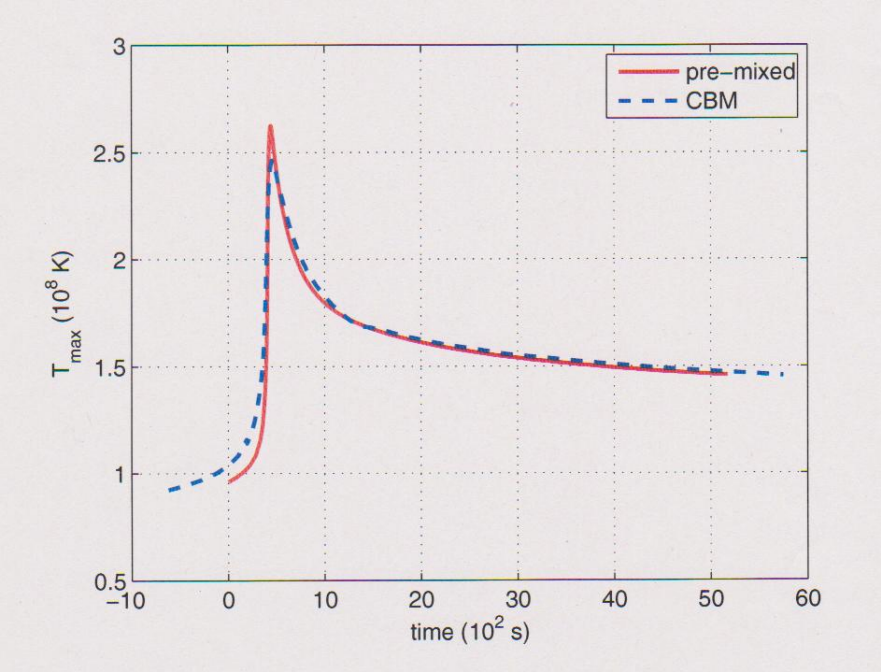


A nova outburst occurring on a 1.15M_{sun} ONe white dwarf with T_c = 12 MK that accretes solar-composition material with the rate of 2×10^{-10} M_{sun}/yr; the CBM is modeled using the exponentially decaying diffusion coefficient with f_{nova} = 0.004 ($f_{He\text{-}shell}$ = 0.01, Falk Herwig)

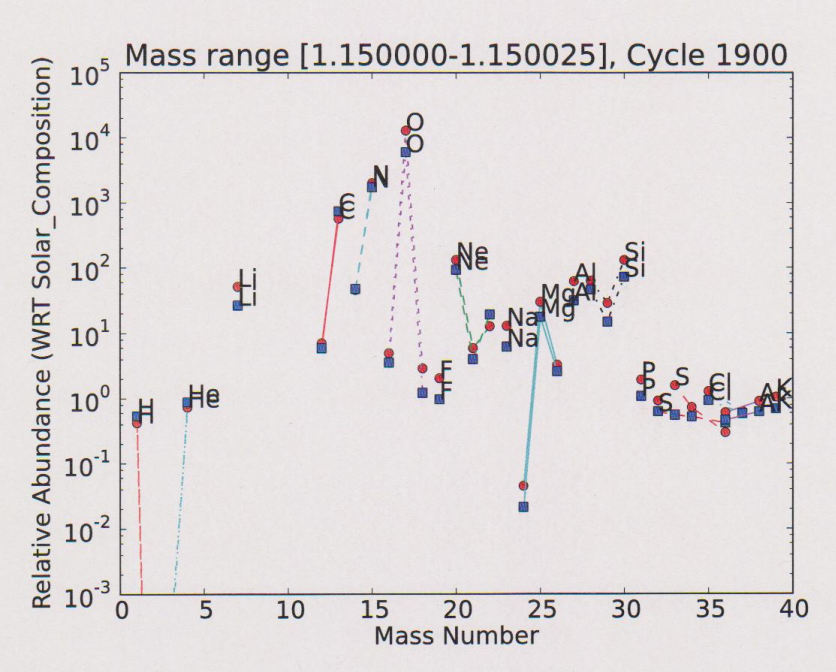


$D_{CBM}(r) = D_{MLT}(r_0) \times \exp(-2|r-r_0|/fH_p)$ (Convective Boundary Mixing)

Comparison of the results obtained with the pre-mixed and CBM ONe nova models



T_{max} -trajectories extracted from MESA models



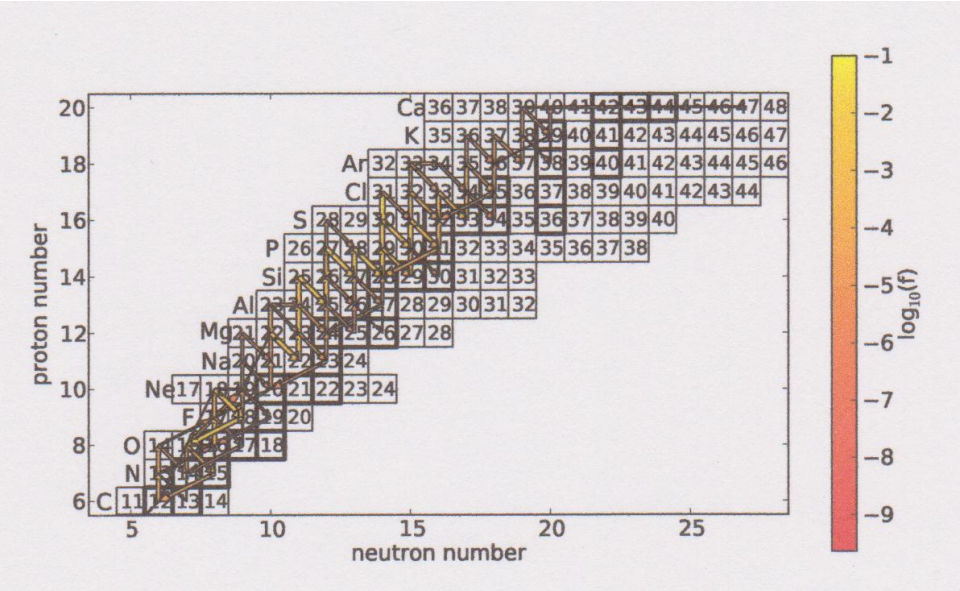
Solar-scaled final abundances computed with NuGrid's multi-zone post-processing nucleosynthesis (MPPNP) code

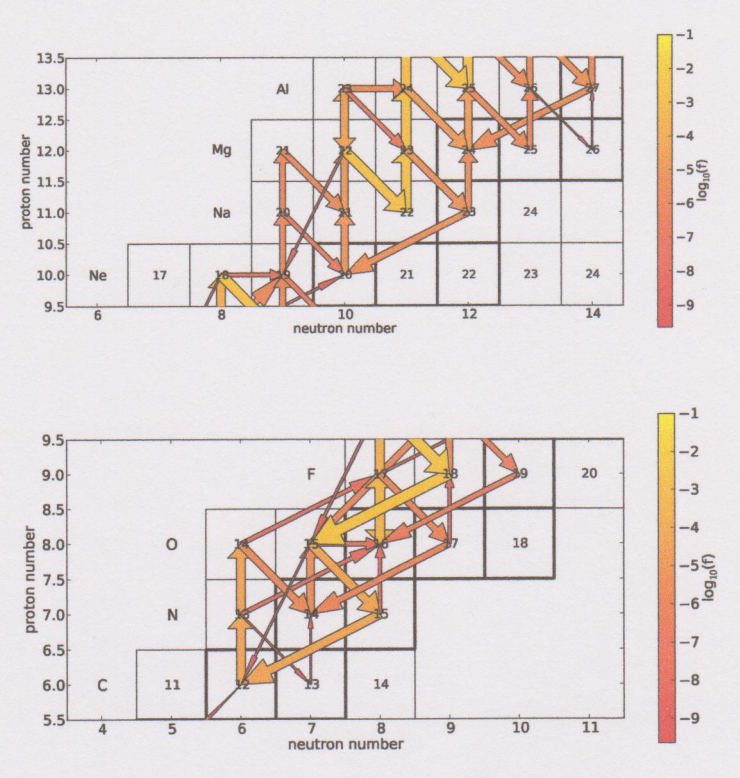
Nuclear networks used in our MESA and NuGrid nova simulations

- MESA CO nova models: nova.net (33 isotopes from H to ^{26}Mg coupled by 65 reactions)

- MESA ONe nova models: nova_ext.net (48 isotopes from H to ^{30}Si coupled by 120 reactions and nova_weiss.net (120 isotopes with 440 reactions)

- NuGrid SPPN and MPPNP post-processing of MESA nova models: 147 isotopes coupled by more than 1700 reactions





T_{max}= 408 MK (H, He, Li, Be, and B isotopes are not shown); SPPN post-processing of our 1.3M_{sun} ONe nova model with T_c = 7 MK and dM/dt = 10^{-11} M_{sun}/yr

Comparison of our results with those reported by the Barcelona group (Jose & Hernanz)

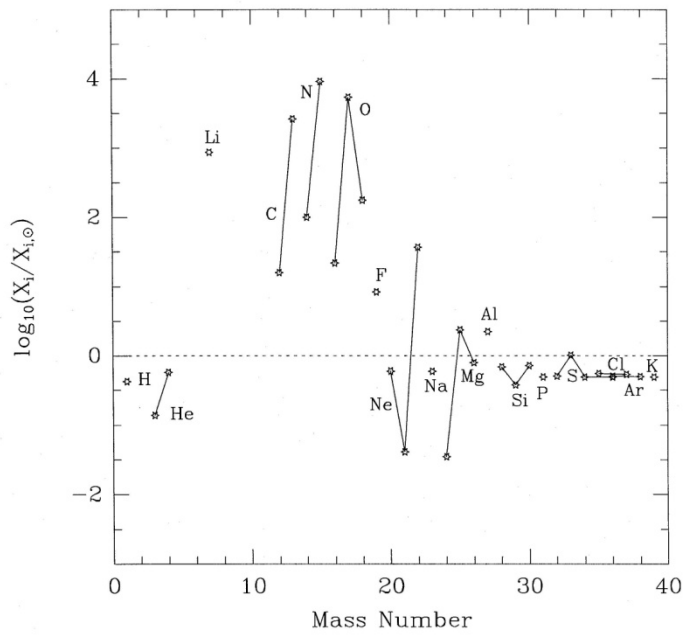


FIG. 1.—Overproduction factors relative to solar abundances vs. mass number for model CO5 (1.15 $M_\odot$ CO white dwarf with 50% mixing).

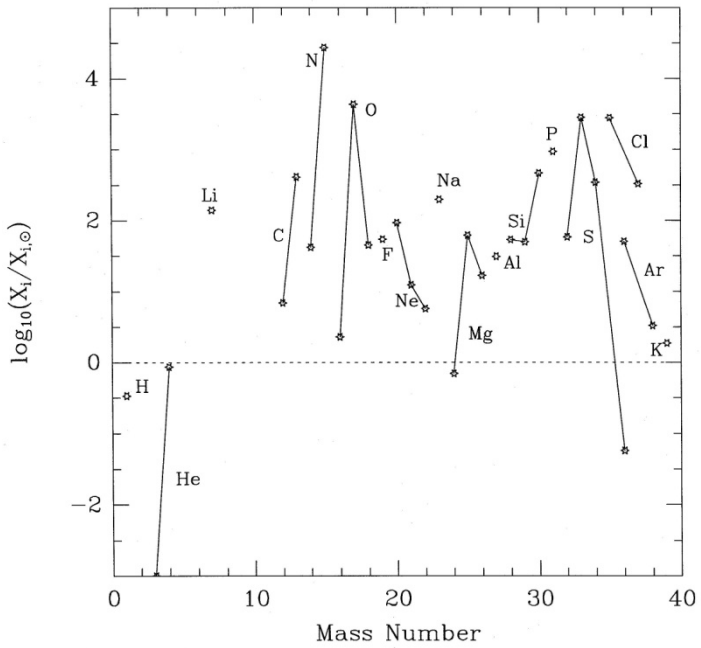
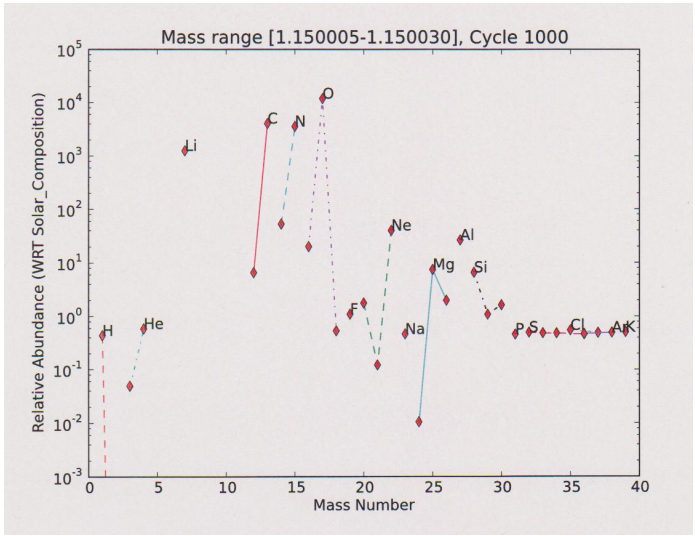
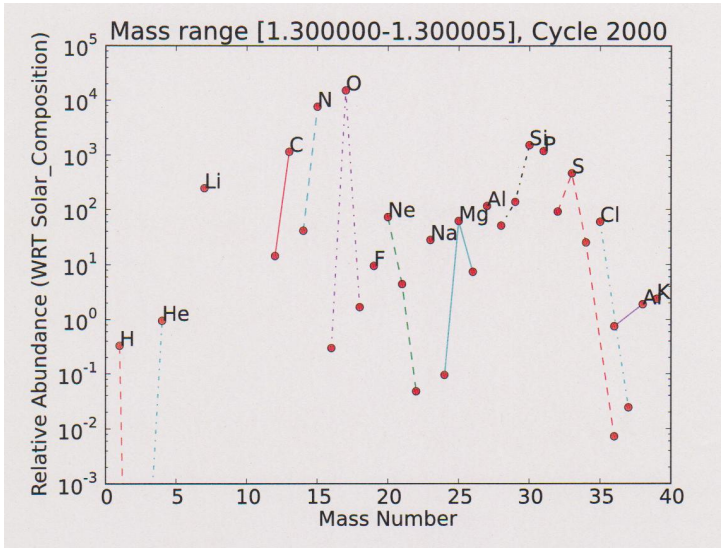


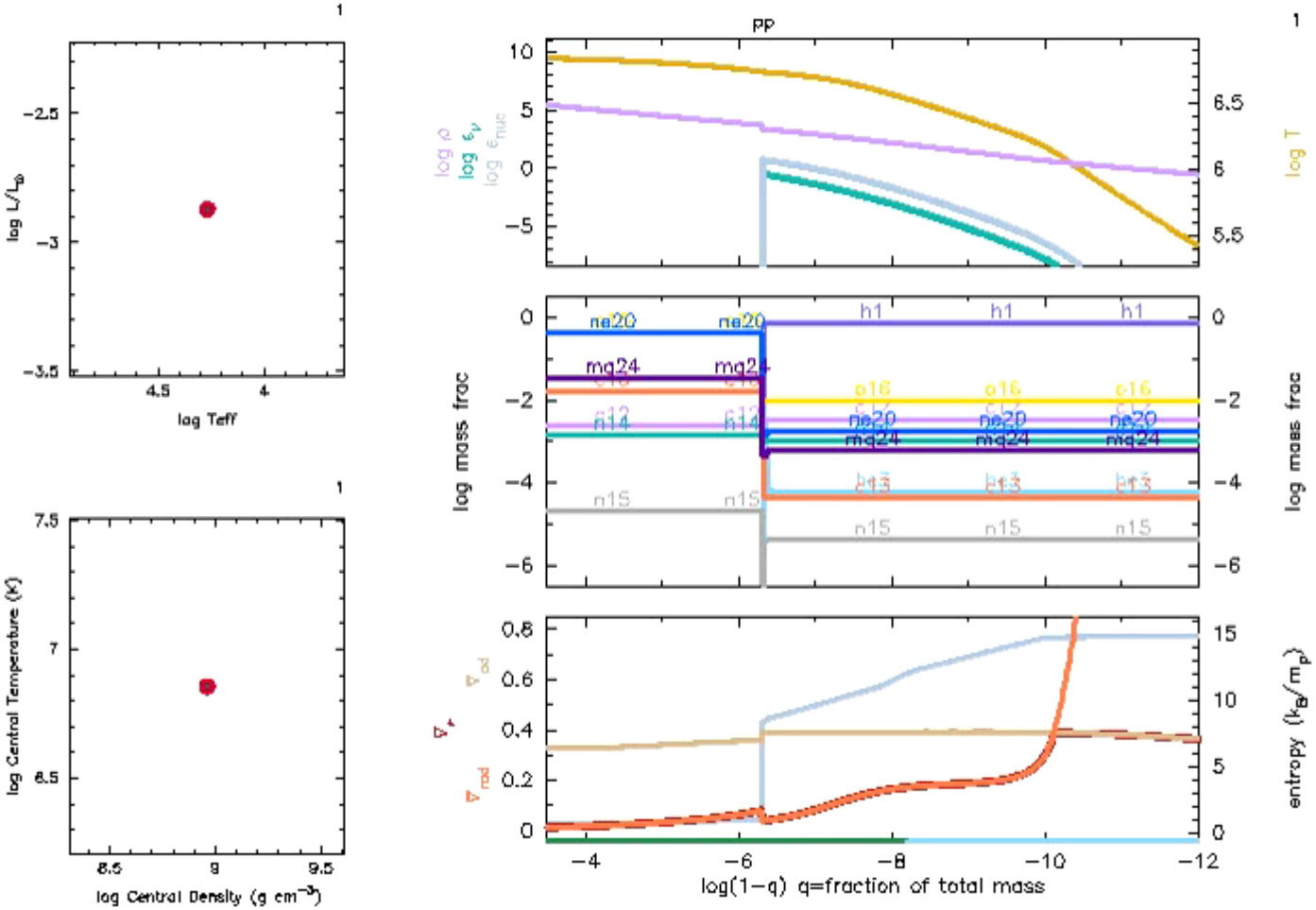
FIG. 3.—Same as Fig. 1, but for model ONe6 (1.35 $M_\odot$ ONe white dwarf with 50% mixing).



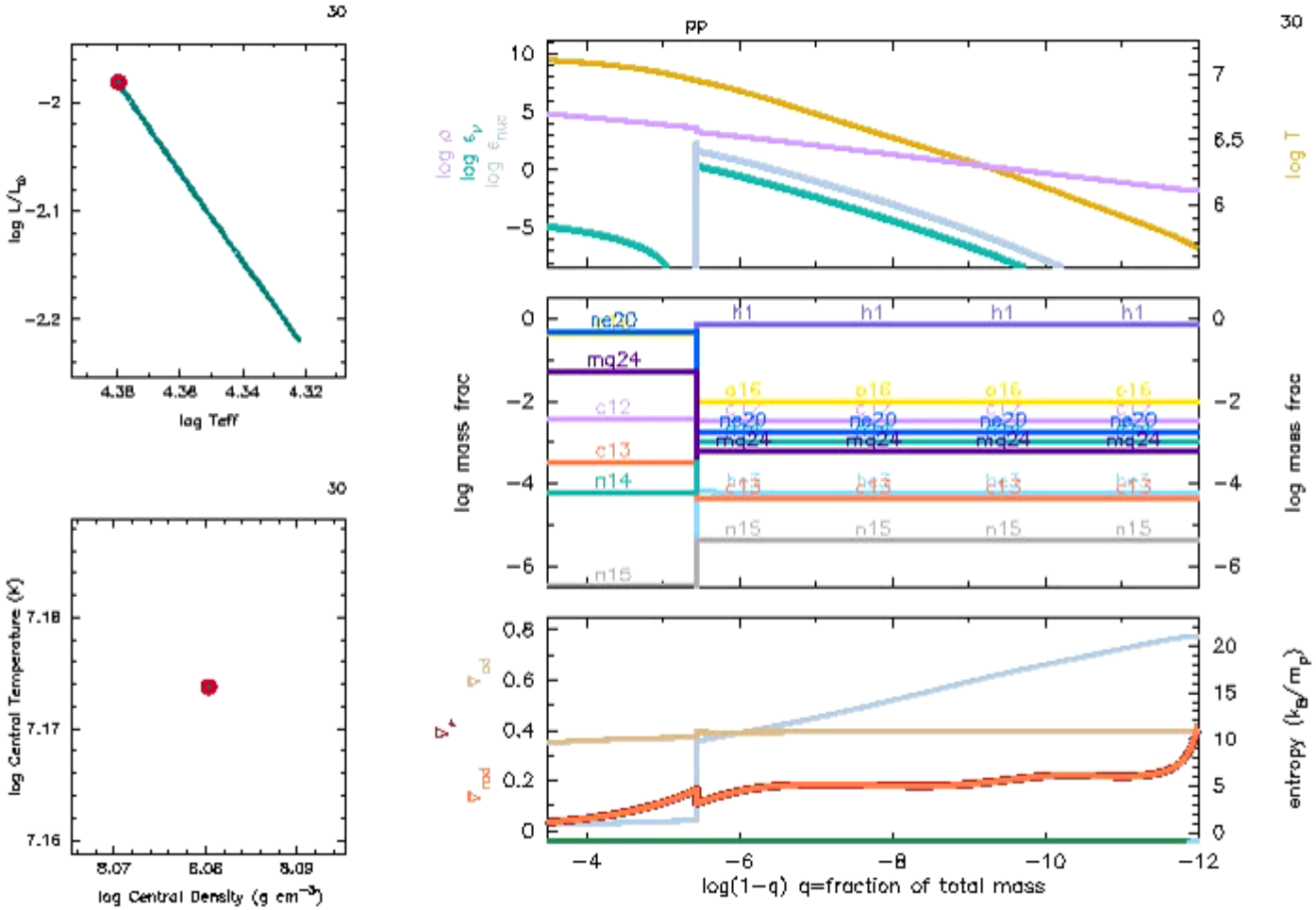


Effects Caused by ^{3}He Burning

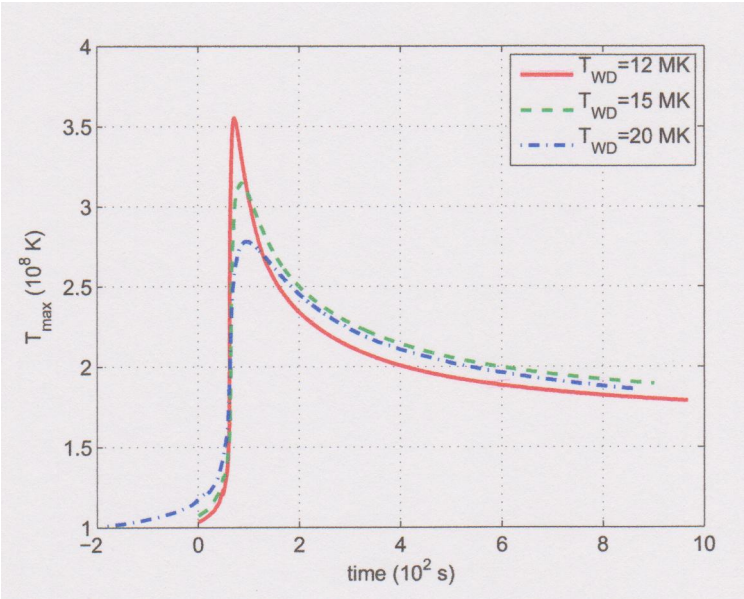
A nova outburst occurring on a 1.3M_{sun} ONe white dwarf with T_c = 7 MK that accretes solar-composition material with the rate of 10^{-11} M_{sun}/yr; the ^{3}He-triggered convection

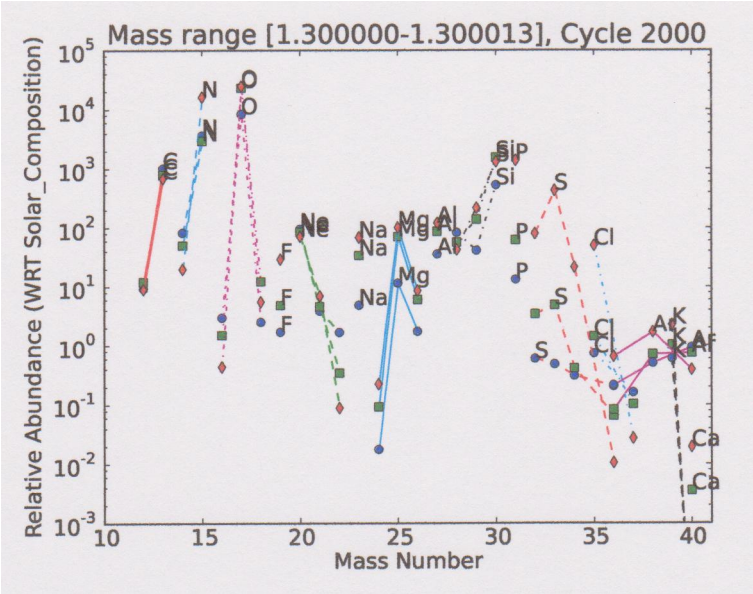


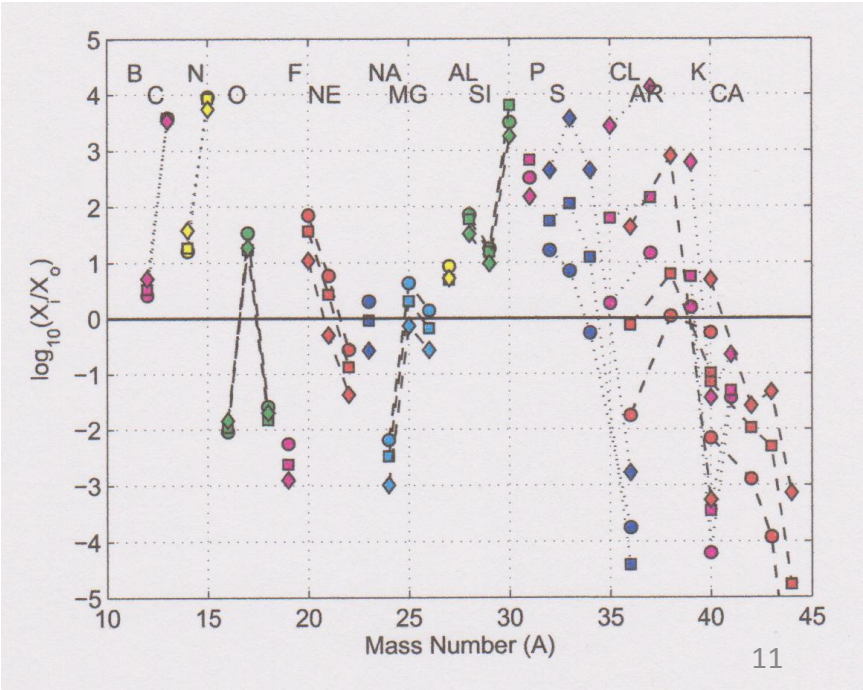
A nova outburst occurring on a 1.15M_{sun} ONe white dwarf with T_c = 15 MK that accretes solar-composition material with the rate of 10^{-10} M_{sun}/yr; the formation of a buffer zone



NuGrid's SPPN vs MPPNP

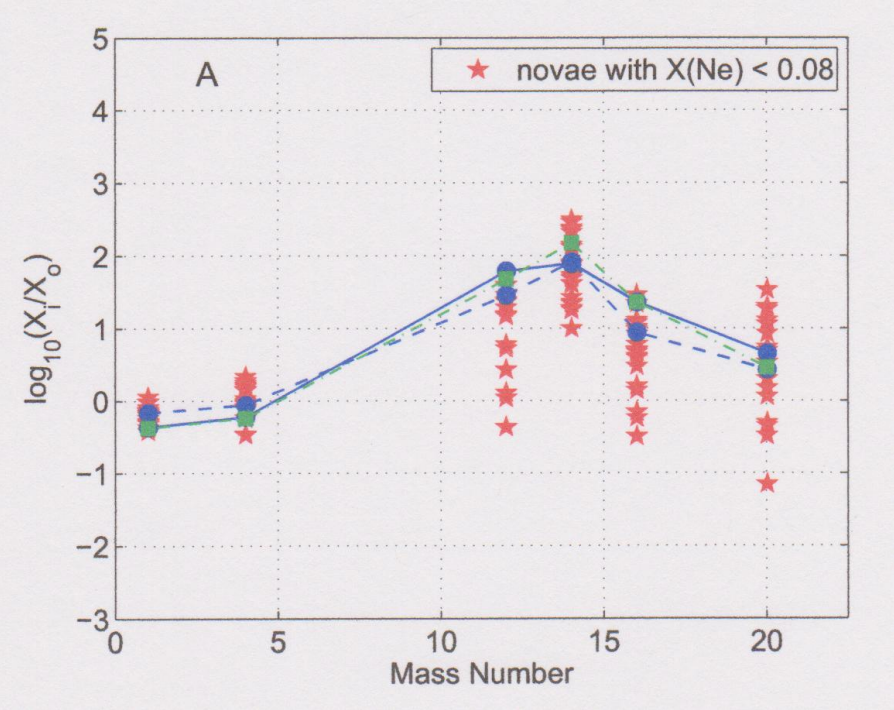


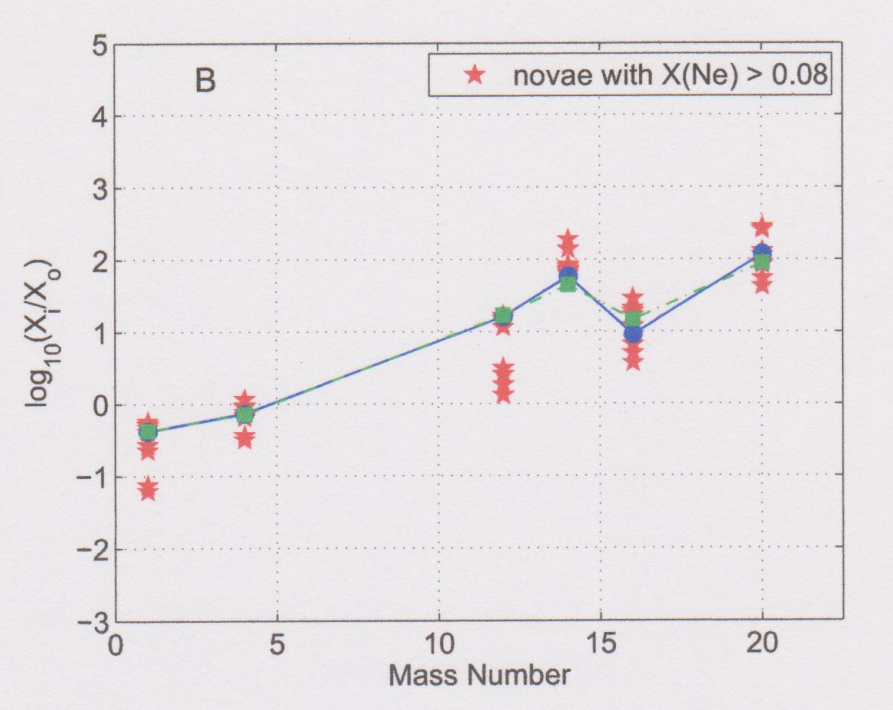




Comparison of the results of post-processing nucleosynthesis computations for 1.3M_{sun} ONe nova model with different WD's initial central temperatures obtained using the multi-zone MPPNP code (upper-right) and single-zone SPPN code (lower-right).

Comparison with the observed element abundances in novae from optical and ultraviolet spectroscopy





Red star symbols are data from Table 2 of Gehrz et al. (1998, PASP, 110, 3)
Blue circles and curves are our results from 1.15M_{sun} nova models; solid and dashed curves show the results for 50% and 25% CO pre-mixed accreted envelopes
Green squares and curves are the results of Jose & Hernanz (1998, ApJ, 494, 680)

Thank you!